A trait-based approach for the choice of cover-crops in banana cropping systems: theoretical developments and practical applications

Gaëlle Damour, Hoa Tran Quoc, Florence Tardy, Charles Meynard, Marc Dorel

CIRAD - UR GECO

ISHS-ProMusa Symposium 2016
Session A: Sharing the concepts of agroecology and illustrating their usage

Banana cover-crop systems of the F.W.I

Monoculture

Complex systems (banana – cover crops – weeds)

Biotic and abiotic constraints :

- Plant-parasitic nematodes (*R. similis*)
- Weeds
- Soil fertility decrease over cycles

Hypothesis of positive effects of synergies and complementarities between species

(Altieri, 1999; Koohafkan et al., 2012; Newton et al., 2009; Tilman et al., 1996; Vandermeer, 1989)

Banana cover-crop systems of the F.W.I

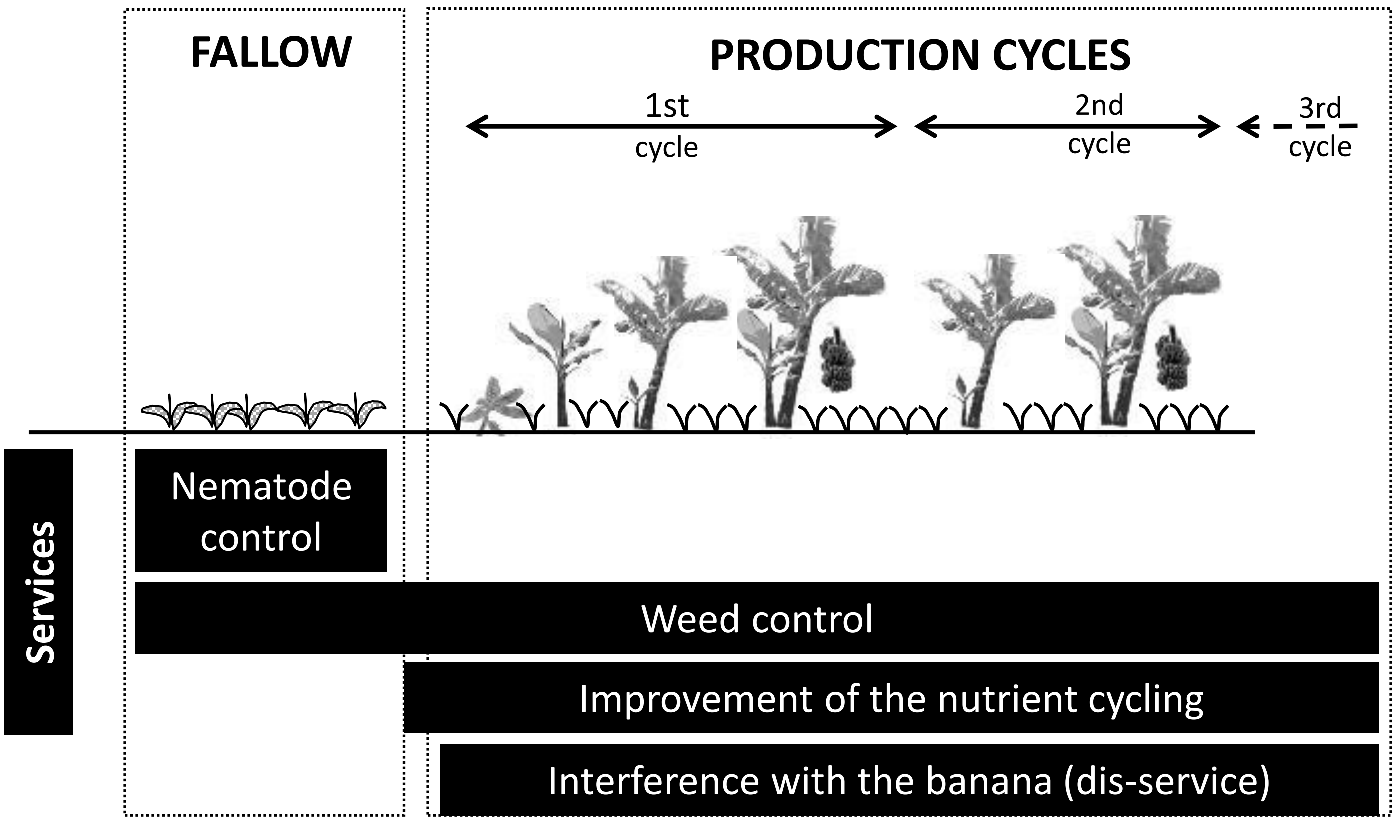
Cover crops used as fallow or during production cycles, to deliver **ecosystem services ***

***** The benefits people obtain from ecosystems

(MAE, 2003)

Banana cover-crop systems of the F.W.I

Cover crops used as fallow or during production cycles, to deliver ecosystem services



Actual benefits result from the balance between services

=> What is the best cover crop for each phase of the cropping system and how to choose it ?

Functional trait approaches applied to agrosystems

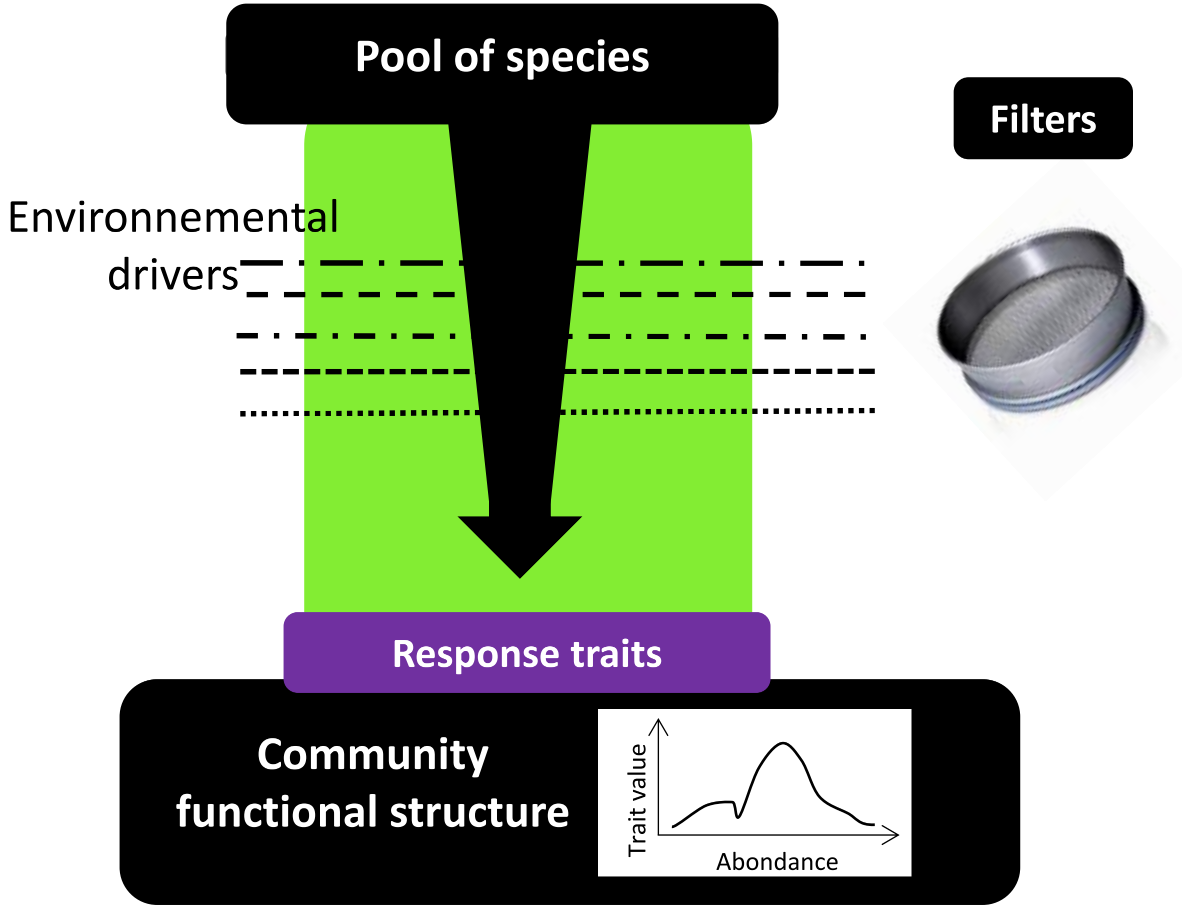
What are functional traits ?

- The morpho-physio-phenological features of an individual that relate to its functioning (Violle et al., 2007)

  ~ simple indicators of plant functions

- Used according to the hypotheses that :

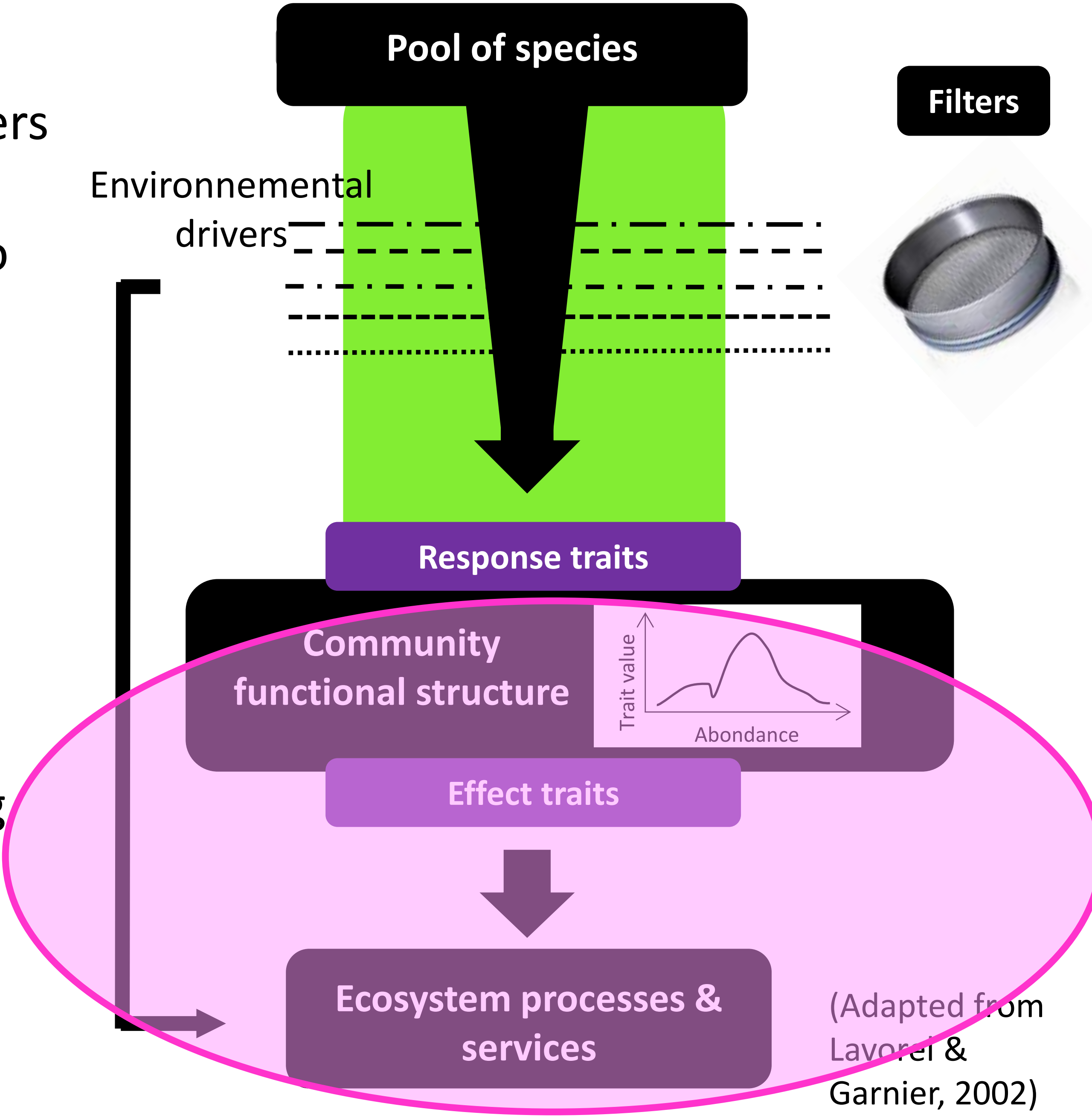
- environmental drivers act as filters sorting species according to the value of their *(response)* traits



(Adapted from Lavorel & Garnier, 2002)

- environmental drivers act as filters sorting species according to the value of their *(response)* traits

- the resulting functional structure of the community impacts ecosystem processes according to *(effect)* trait distribution



(Adapted from Lavorel & Garnier, 2002)

Functional trait approaches applied to agrosystems

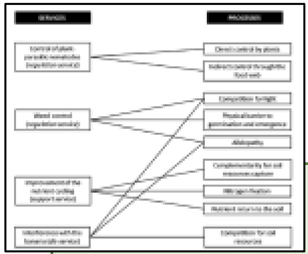
Why using functional traits ?

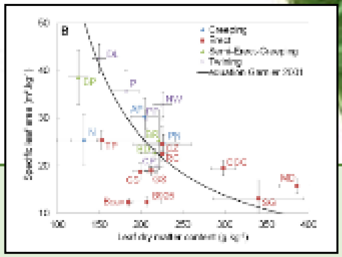
- ❑ to have a framework that enables to assess and analyze the services delivered by plants and plant communities and their response to management

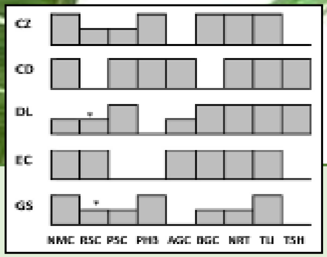
- ❑ to identify general rules of functioning (ex : trade-offs between traits, services, plant strategies…)

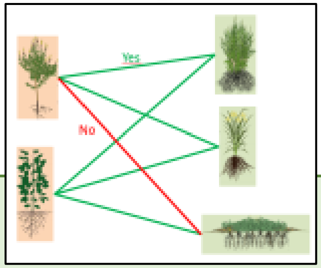
- ❑ to construct tools to help the choice of the best plants and the design of multi-species cropping systems

A continuum from theoretical developments to practical applications









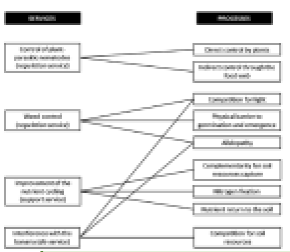
A framework to assess agrosystem services using functional traits

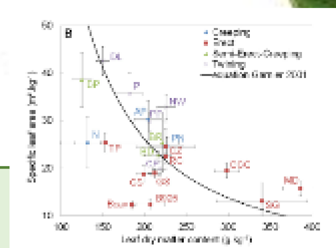
Identification of trade offs of functioning & plant strategies

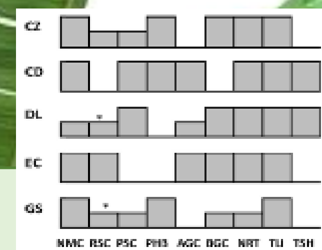
Construction of plant functional profiles

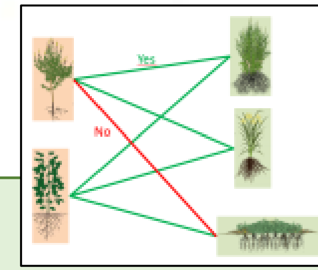
Design & management of covers based on “engineering traits”

A continuum from theoretical developments to practical applications









A framework to assess agrosystem services using functional traits

Identification of trade offs of functioning & plant strategies

Construction of plant functional profiles

Cover design & management based on "engineering traits"

Functional traits used to asses the services delivered by cover crops – A review of literature

CHAPTER THREE

Using Functional Traits to Assess the Services Provided by Cover Plants: A Review of Potentialities in Banana Cropping Systems

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Services & Processes

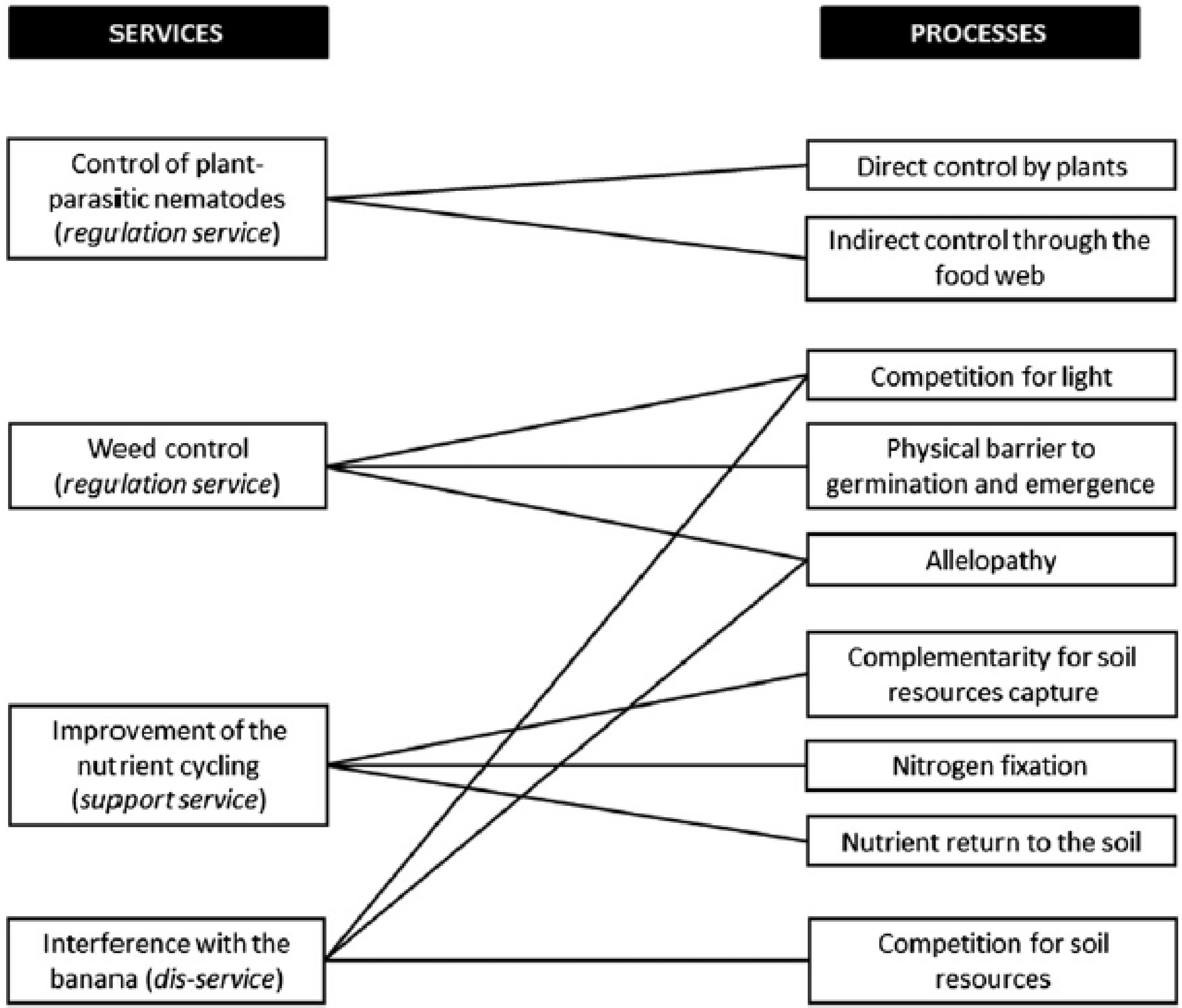


Figure 2 The four main targeted services and dis-service in banana cropping systems and the associated agrosystem processes. Lines indicate the relationships between services and processes that were considered in this article.

Damour et al. (2015)

Processes & Traits

Table 1 Cover plants characteristics considered as markers of the main ecosystem processes associated with the services and dis-service expected in a banana—cover plant cropping system (a semiperennial cropping system). Markers are defined at three levels of organization: organisms (plant traits *sensu sticto*) (plain text), populations (density of individuals) (**text in bold**), and communities or in interaction with other organisms (*text in italics*). "Primary markers" are proposed to assess the agrosystem processes on the basis of their ease of acquisition and of their relevance. "Secondary markers" are considered more complicated to acquire and/or less relevant to assess the processes. For a better analysis, processes are decomposed into their main components. The direction of the markers–processes relationships is indicated between brackets. Abbreviations are given in Table 3—cont'd

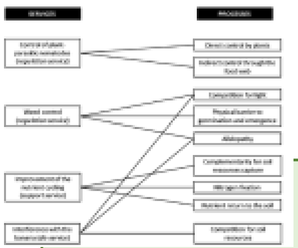
Agrosystem processes	Main components of the processes	Primary markers	Secondary markers
Competition for light			
Competitive growth against weeds	Importance	Projected area (+)	Aboveground biomass (+)—Height (+)—Maximal diameter of the ellipse in which the plant is embedded (+)
	Rapidity	Seed mass (−)—*SLA* (+)	Height growth rate (+)—***LAI*** (+)—*RGR$_a$* (+)—*LAR$_a$* (+)—*NAR$_a$* (+)—*LMR$_a$* (+)
	Persistence	Plant life history	Leaf habit—Organs activities (−)—Shoot/root ratio (−)—Morphological or physiological traits related to the plant ability to survive stresses

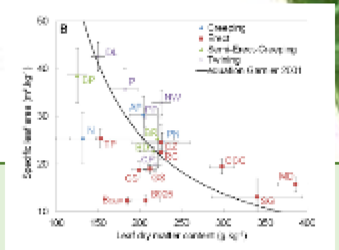
⇒ **A shortlist of traits (or markers) to be used to assess agrosystem processes**

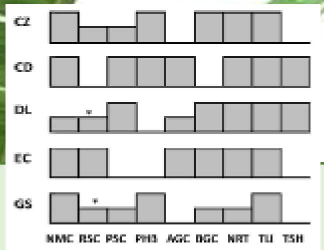
⇒ **Hypothesis on trade-offs and synergies among services**

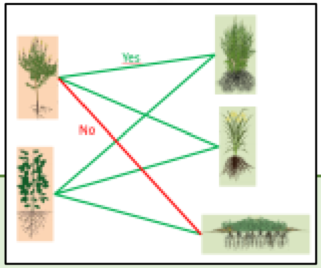
Damour et al. (2015)

A continuum from theoretical developments to practical applications









A framework to assess agrosystem services using functional traits

Identification of trade offs of functioning & plant strategies

Construction of plant functional profiles

Design & management of covers based on “engineering traits”

weed control
by competition for ressources

Europ. J. Agronomy 71 (2015) 10–18

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Trait-based characterisation of cover plants' light competition strategies for weed control in banana cropping systems in the French West Indies

Flo

[a] CIRA
Capes
[b] INRA

Trait-based characterisation of soil exploitation strategies of banana, weeds and cover plant

Europ. J. Agronomy 74 (2016) 103–111

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Leaf area development strategies of cover plants used in banana plantations identified from a set of plant traits

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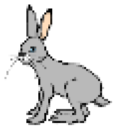
Resource acquisition trade-offs among cover plants

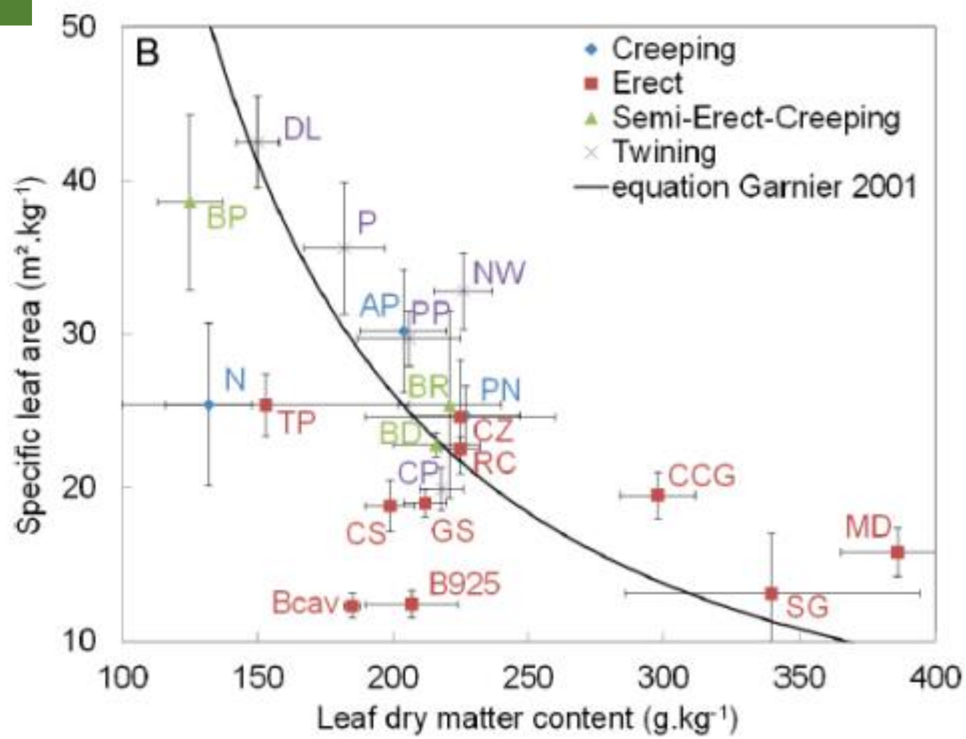
Aboveground



Acquisitive strategy

- Fast growth rate
- Short life cycle
- High photosynthesis rate
- Low conservation of resources

Based on traits of the leaf economic spectrum (Wright et al. 2004)



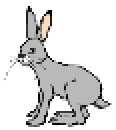
Conservative strategy

⇒ Different abilities to acquire ressources and then to compete with weeds

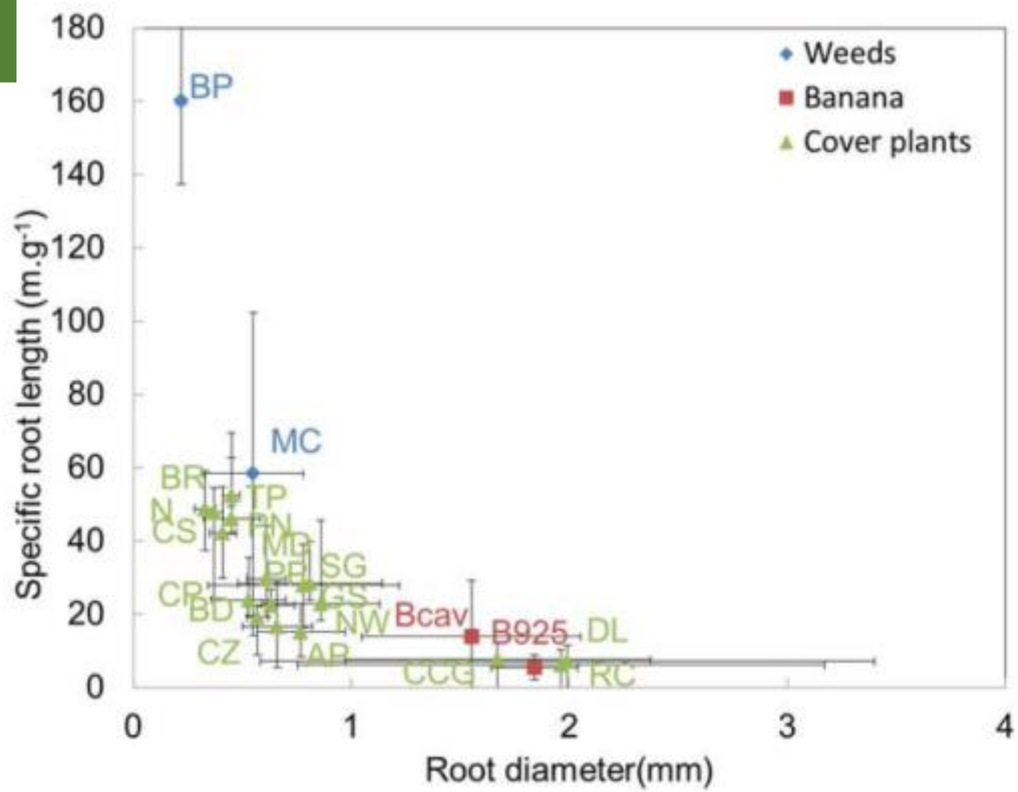
Tardy et al. 2015

Resource acquisition trade-offs among cover plants

Belowground



Acquisitive strategy



Conservative strategy

⇒ Acquisitive species aboveground are not necessarily acquisitive species belowground

Tardy et al. sub.

Leaf area development strategies of cover plants

$$LA_t = SLA \times LMF_a \times f(SM) \times \exp(t \times RGR_a)$$

Specific leaf area (m²/g)

Leaf mass fraction (g/g)

Seed mass (g/g)

Relative growth rate (g/g/d)

Damour et al. 2016

Leaf area development strategies of cover plants

$$LA_t = SLA \times LMF_a \times f(SM) \times \exp(t \times RGR_a)$$

4 strategies of leaf area development :

	G1	G2	G3	G4
Seed mass		+++		
Leaf mass fraction			+++	
Relative growth rate		---	+++	
Specific leaf area	+++			

G1: allocating a large part of biomass to the leaf area development

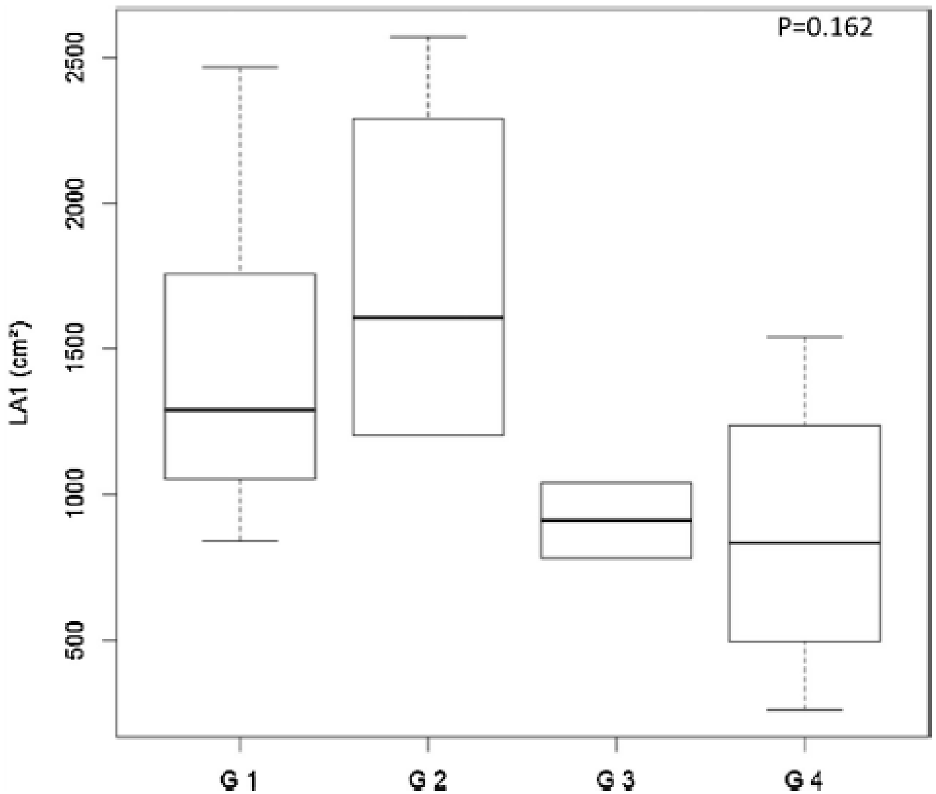
G2: high biomass and leaf area at emergence

G3: rapid growth in biomass and low investment in leaf biomass

G4: non-specialized strategy

Damour et al. 2016

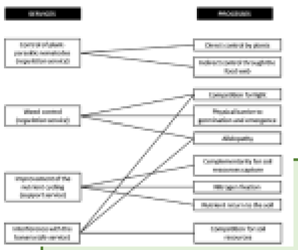
Leaf area development strategies of cover plants



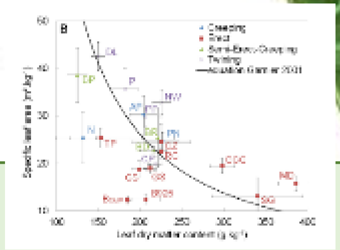
⇒ groups of plants sharing a same strategy performed differently

Damour et al. 2016

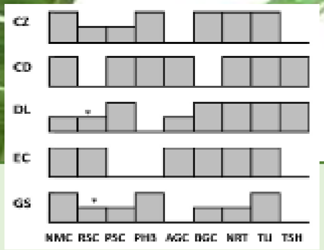
A continuum from theoretical developments to practical applications



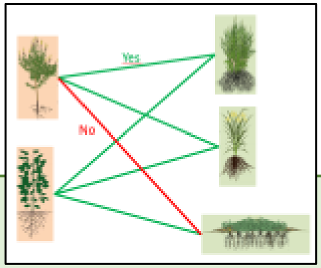
A framework to assess agrosystem services using functional traits



Identification of trade offs of functioning & plant strategies



Construction of plant functional profiles



Design & management of covers based on “engineering traits”

Functional profiles of cover plants

Europ. J. Agronomy 52 (2014) 218–228

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A trait-based characterization of cover plants to assess their potential to provide a set of ecological services in banana cropping systems

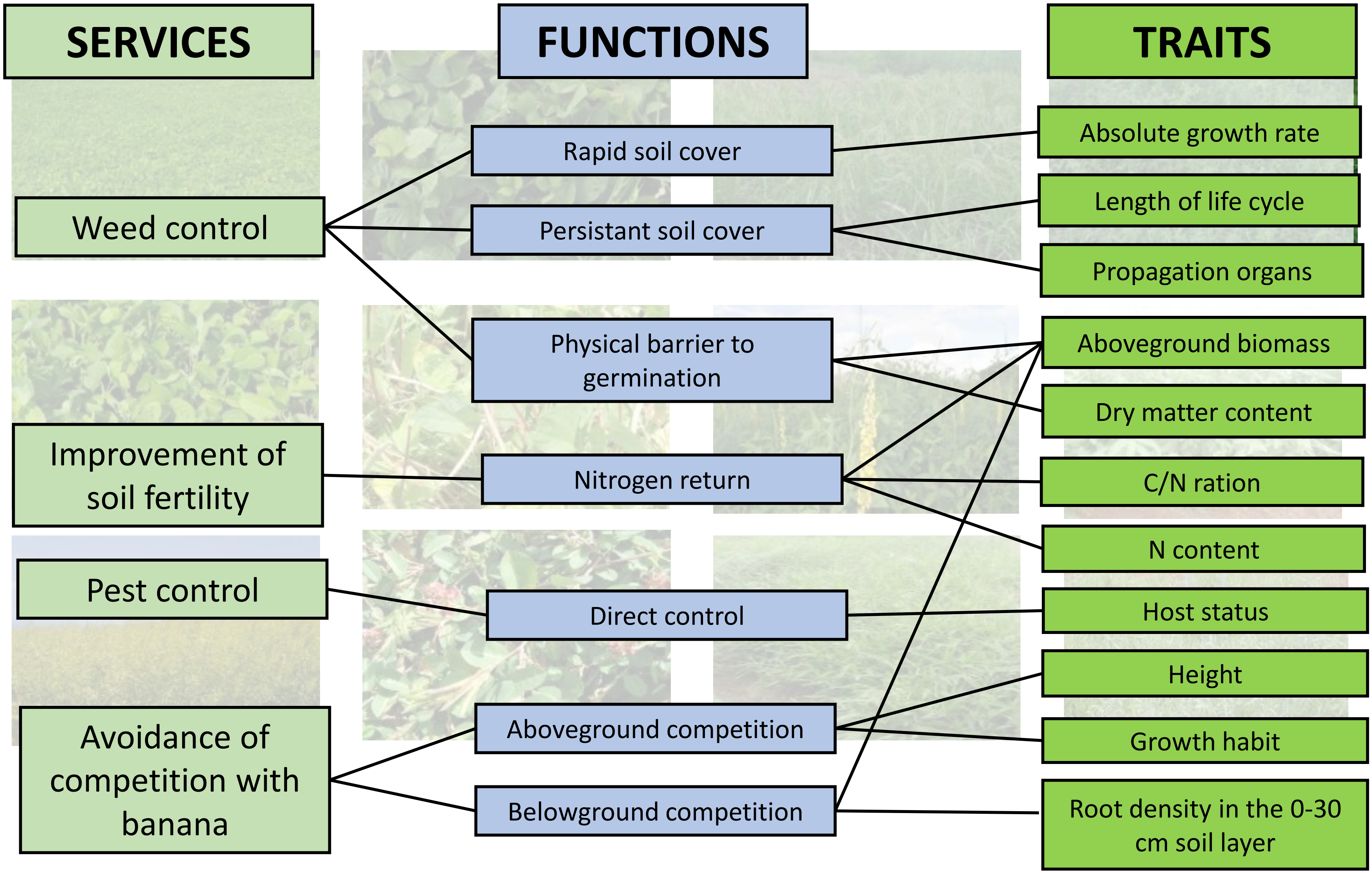
CrossMark

Gaëlle Damour[a,*], Marc Dorel[a], Hoa Tran Quoc[a], Charles Meynard[a], Jean-Michel Risède[b]

[a] *CIRAD Persyst – UR Systèmes de culture à base de bananiers, ananas et plantains, Station de Neufchateau, Sainte Marie, 97130 Capesterre-Belle-Eau, Guadeloupe*

[b] *CIRAD Persyst – UR Systèmes de culture à base de bananiers, ananas et plantains, PS4, Boulevard de la Lironde, 34398 Montpellier Cedex 5, France*

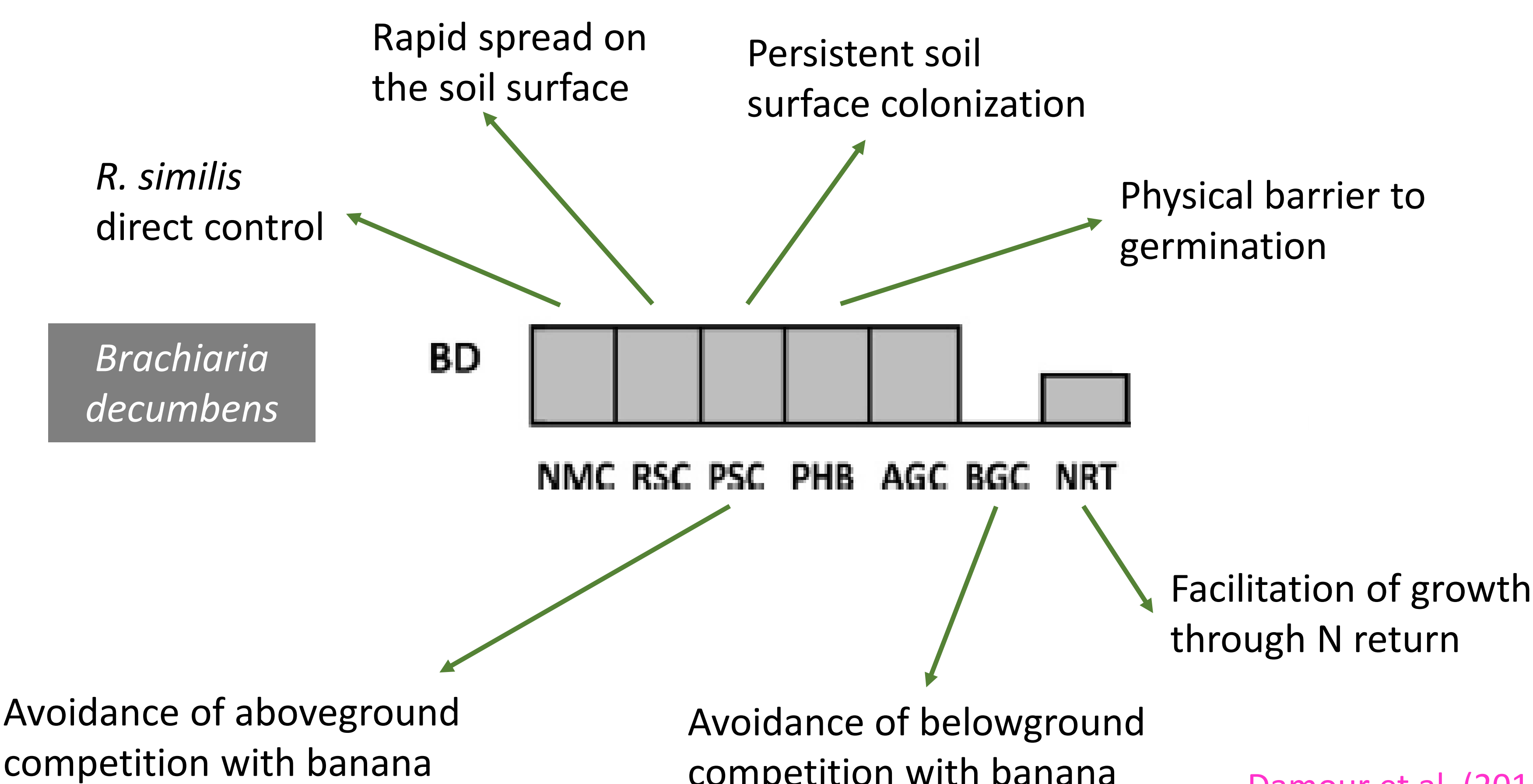
Trait characterization of a collection of cover crops



Damour et al. (2014)

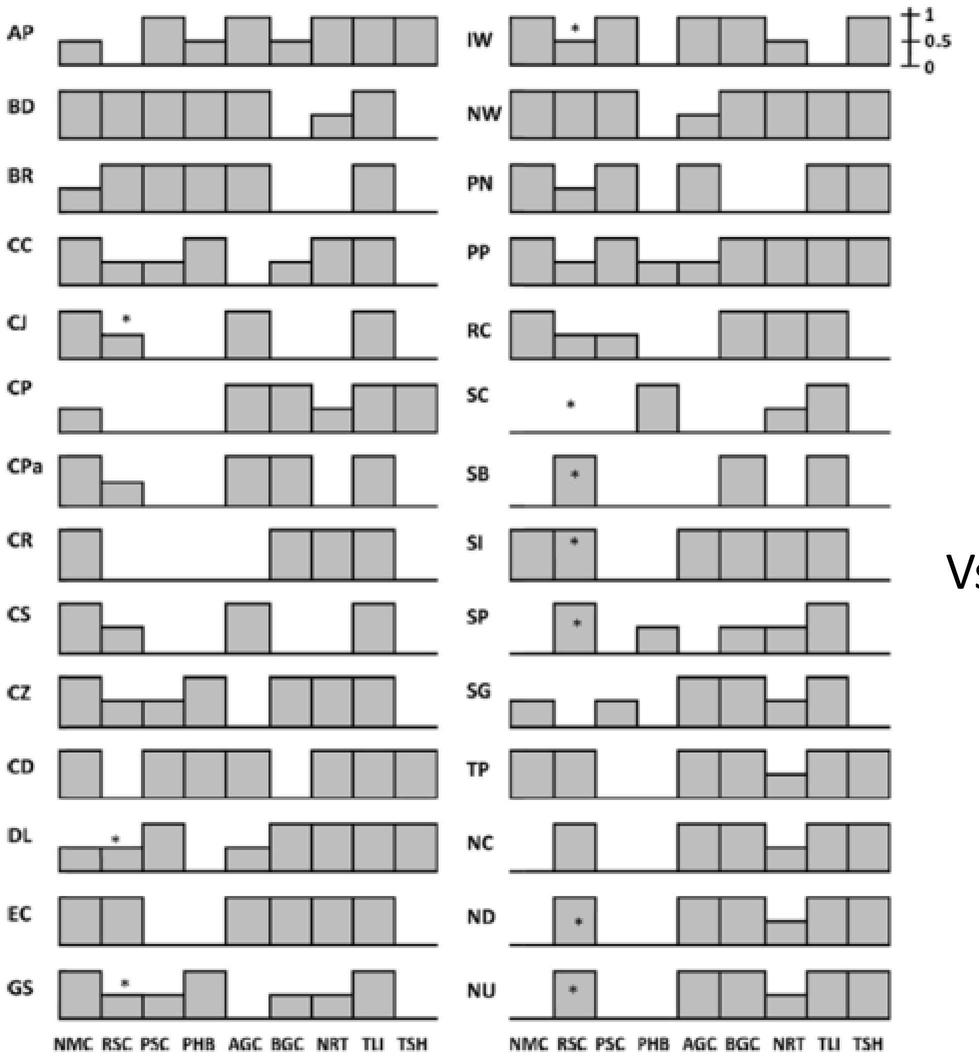
Construction of functional profiles

Trait values **+** Thresholds established according to knowledge on plants or system functioning **=>** Satisfactory levels of the function



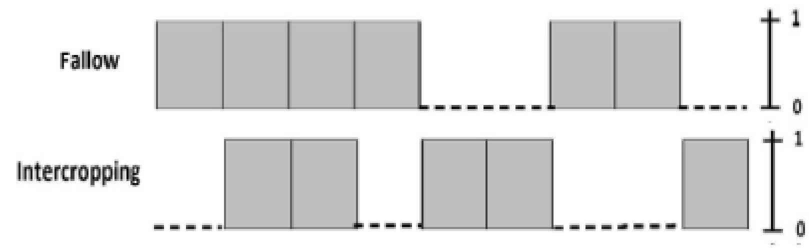
Damour et al. (2014)

Comparison of cover plants functional profiles with ideal profiles for different usages



Cover plants functional profiles

Vs.



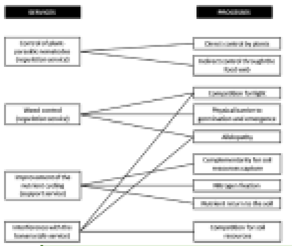
Usages

⇒ Profiles rarely match exactly

⇒ Cover crop mixtures should be prefered

Damour et al. (2014)

A continuum from theoretical developments to practical applications



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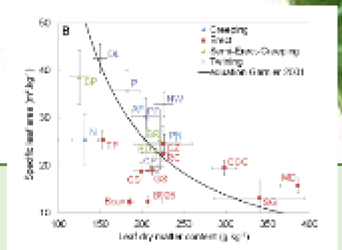

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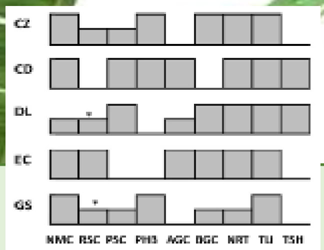
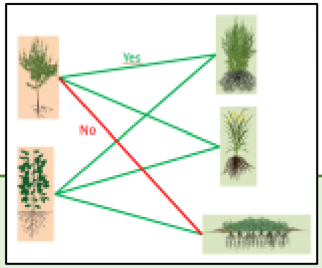


Construction of plant functional profiles



Design & management of covers based on "engineering traits"

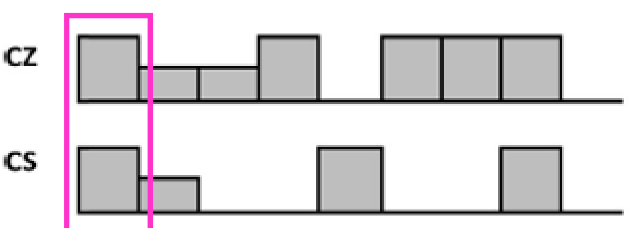
Cover design and management adaptation

Step 1. Species choice according to the services expected (functional profiles)

For fallow period :

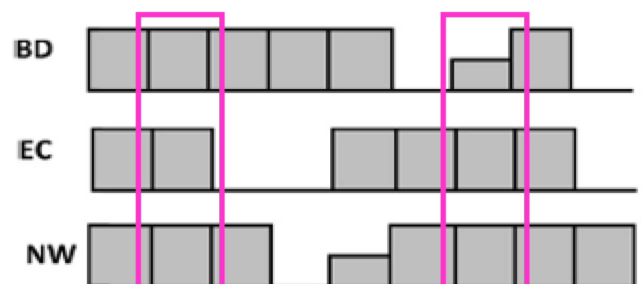
R. Similis control

C. zanzibarica *C. spectabilis*



Weed control, improvement of soil nutritional status

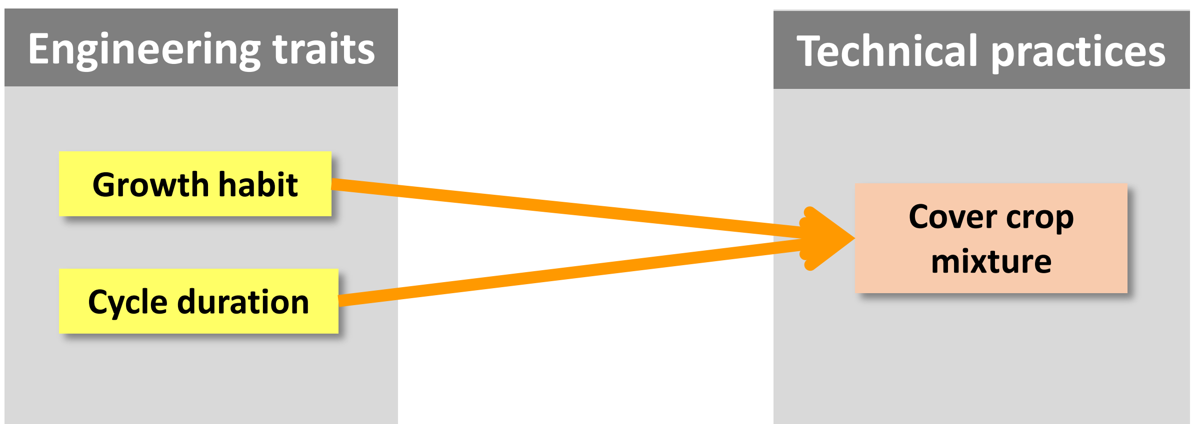
B. decumbens *E. coracana* *N. wightii*



Cover design and management adaptation

Step 1. Species choice according to the services expected (functional profiles)

Step 2. Mixture of species with complementary engineering traits



Basic rules :

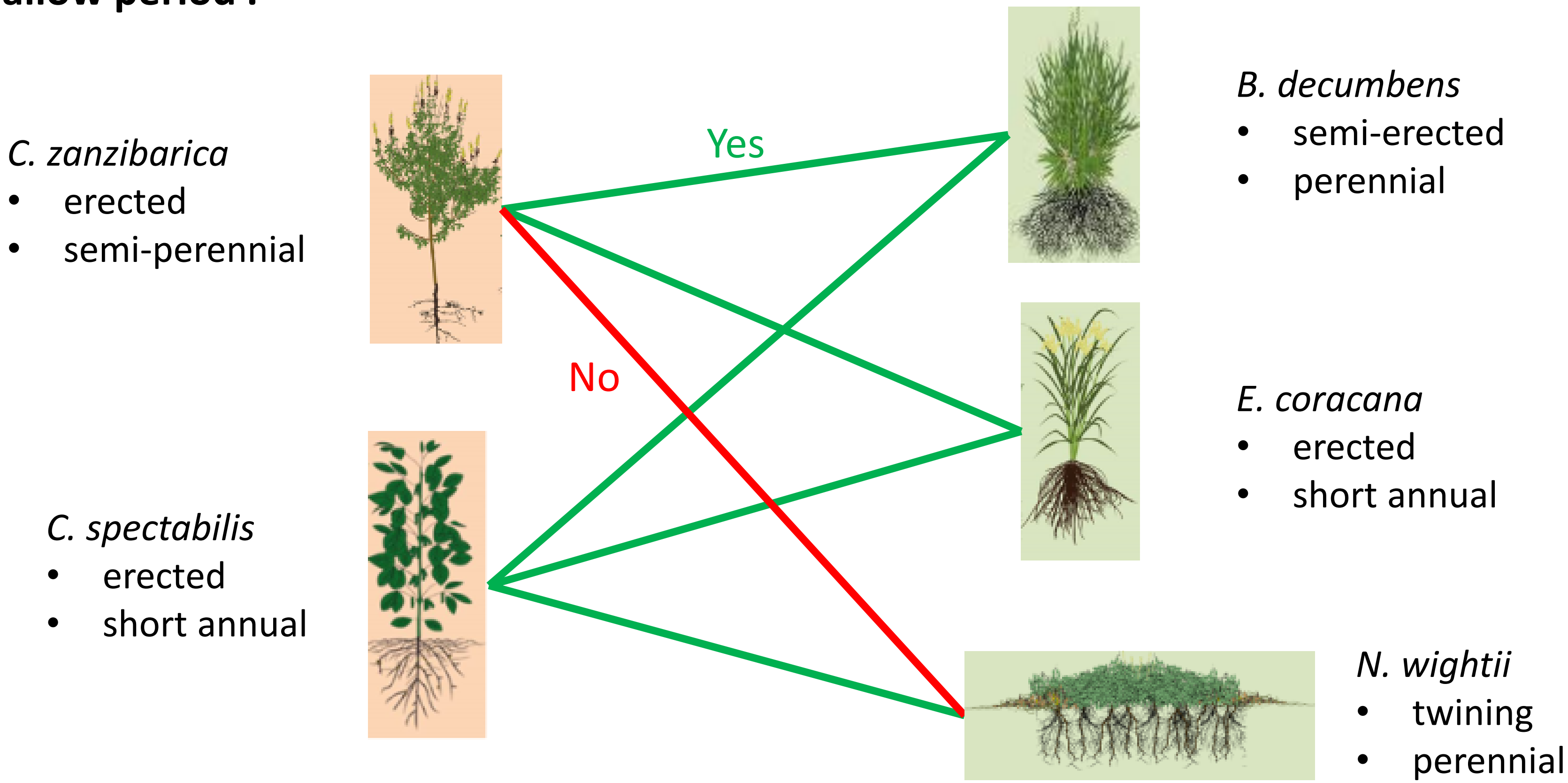
Erected	x	Erected
Creeping	x	Erected
Twining	x	Erected, short cycle

Cover design and management adaptation

Step 1. Species choice according to the services expected (functional profiles)

Step 2. Mixture of species with complementary engineering traits

For fallow period :

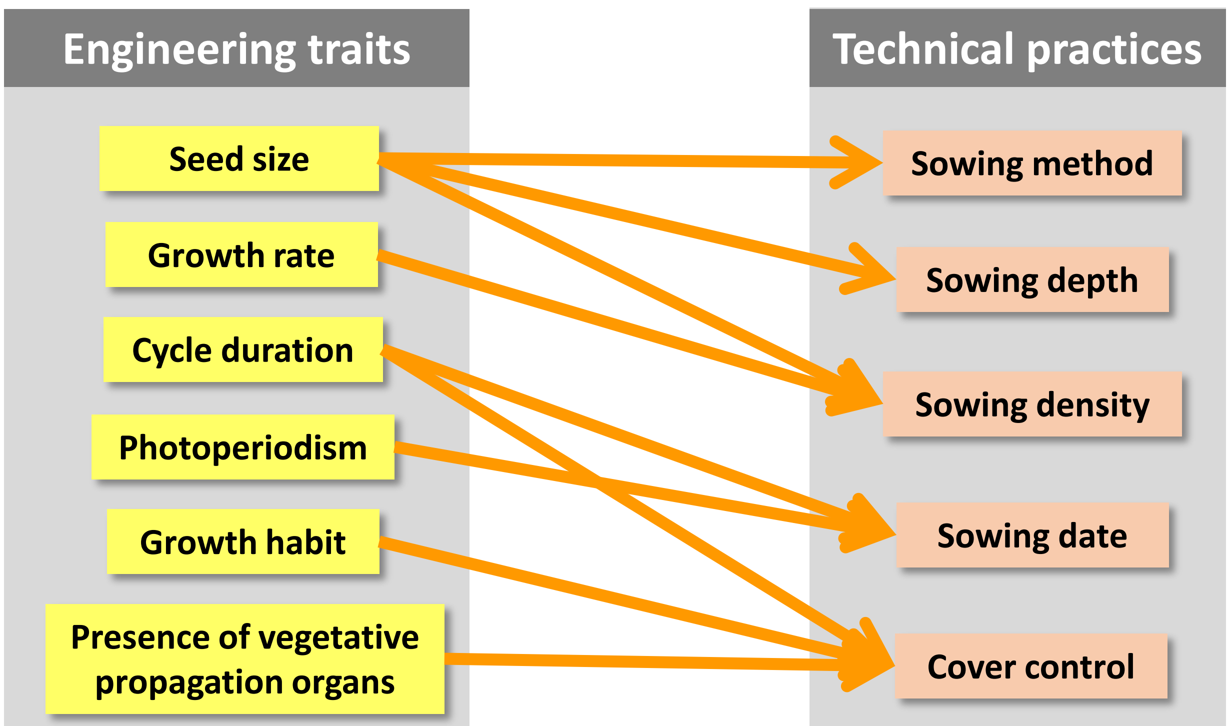


Cover design and management adaptation

Step 1. Species choice according to the services expected (functional profiles)

Step 2. Mixture of species with complementary engineering traits

Step 3. Adaptation of technical practices



Conclusion

- ✓ Functional traits have a high potential to resolve questions related to the design of multispecies cropping systems that deliver the best compromise between services

- ✓ Further theoretical developments are needed

- ✓ Trait-based approaches deserve a wider application in agrosystems to carry the reflections forward

Three other major papers on the use of functional traits in agrosystems

- Garnier & Navas 2012 - Agronomy for Sustainable Development - 32: 365-399
- Martin & Isaac 2015 - Journal of Applied Ecology - 52: 1425-1435
- Wood et al. 2015 - Trends in Ecology & Evolution - 30: 531-539


Thank you for your attention